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Assessing opportunities for organic tomato farming: a PESTEL perspective on sustainable agriculture

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PESTEL research determines organic tomato farming chances in North Sulawesi Province, Indonesia. This mixed-method study interviews 100 consumers and 20 farmers. This study indicates that environmental and social awareness increases the organic tomato market's capacity to improve agricultural sustainability. Market access and farmer yields will improve with government help, public knowledge, and technical advancement. Thus, many organic farmers can balance yields and incomes. Disastrous weather, pests, and diseases are hurdles. Farmers with organic certification earn more and produce more sustainably. This report stresses the necessity for concerted efforts to overcome historical limitations and improve organic tomato production. Government, farmers, and research organizations must collaborate to enhance agricultural practices and yields. Knowledge of the sector's external environment can help stakeholders improve sustainable agricultural policies and initiatives. This study advances organic farming science and helps the agriculture industry's future. This study supports an eco-friendly approach that meets customer and market needs. This study can help policymakers and practitioners improve contemporary, ecological agriculture worldwide.

Keywords: Organic agriculture, climate change, vegetable cultivation, environmental sustainability, consumer awareness, agricultural policy.

INTRODUCTION

Due to global issues including food supply, global warming, and soil degradation, organic farming is becoming more sustainable (Smith et al., 2020). Willer et al. (2021) and Nguyen et al. (2019) reported a global organic product market, organic food and consumer shopping attitudes (Willer et al., 2021; Nguyen, 2019). The Research Institute of Organic Agriculture FiBL reported that global organic product market are predicted to grow (Schlatter et al., 2024). Tandon et al. (2020) suggested that customers are becoming more aware of organic product health benefits. Because less risky ecological approaches reduce toxicity, organic farming helps prevent environmental damage. Due to the risks of traditional agricultural practices that involve hazardous materials and processes, all nations now value organic farming (Montgomery & Biklé, 2021; Naidu et al., 2021). Organic farming technology and approaches expanded tomato cultivation globally (Lastochkina et al., 2022; Salehi et al., 2019). Multi-segmental strategy analysis can be used to define the market by political, economic, social, technical, environmental, and legal (PESTEL) variables (Madureira et al., 2024). Researchers use PESTEL to assess external factors that could affect earlier prospects (Mihailova, 2020; Tahat et al., 2020). Despite international interest in organic farming, farmers continue to struggle with tomato cultivation (Chanda et al., 2021). Lack of information, resources, and training hinder the adoption of organic farming (Diacono et al., 2019; Łuczka & Kalinowski, 2020) that eventually discourage many farming communities. The issue also involves external factors, such as legislation that hinders market developments and, most importantly, climate change (Muluneh, 2021). This requires a thorough investigation of the external environment to identify optimal exploitation chances

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(Hussain et al., 2021). Organic tomato growing development aspects are rationally structured using the PESTEL framework. Identifying difficulties that affect organic tomato farmers and understanding how they may affect the industry's prospects and resilience is necessary.

Despite extensive study on organic farming in varied locales, this report shows gaps in the literature. Agriculture PESTEL study has mostly focused on established economies (Madureira et al., 2024; Muhardi, 2020), with less research on rising economies like Indonesia. Previous organic tomato farming research has concentrated on either technical or market difficulties, not the external environment as this study did (Li et al., 2020; Suri & Udry, 2022).

The current work aims to conduct a PESTEL analysis to examine these concerns further (Ye et al., 2020). This analysis is expected to reveal valuable findings that will help overcome these challenges and improve the creation of superior practices in organic farming (Melovic et al., 2020). Building upon these objectives, this study addresses two interconnected research questions: *What is the extent of interconnections among PESTEL factors for the viability and growth of organic tomato farming in North Sulawesi? How can these insights be used to construct strategies for sustainable agriculture?*

Prior literature has focused only on the technical and practical analysis of the organic farming system (Seitz et al., 2018). Additionally, prior research on organic farming is limited and centered on Java and Sumatra in the Indonesian context (Schreer & Padmanabhan, 2020; Minasny et al., 2020; Fritz et al., 2021). In contrast, the study context of east Indonesia, particularly in North Sulawesi, has not been investigated. However, the more prominent external factors that may influence the effectiveness of organic farming have not been considered (Dessart et al., 2019). What and who are the external forces? This paper seeks to eliminate this deficit by conducting a practical PESTEL analysis. It will view the present state of organic tomato farming and the possible prospects of its further evolution differently.

However, there needs to be more awareness of applying PESTEL analysis in organic farming even as the community mass expands, which is the gap this paper aims to fill. Such a lack is a big problem. This, to some extent, makes this research more likely to offer complete and coherent information than other research studies. Among them, there are patterns that analysts have sometimes excluded during previous analyses.

This research is justified because it is necessary to determine the drivers of this industry, especially given the fluctuating policies and customer pressure on markets. Therefore, this research's findings will add value to advancing knowledge in this field and significantly benefit stakeholders seeking ways to enhance their best agriculture practices.

This study contributes to both theoretical understanding and practical applications in organic tomato farming. The findings will advance knowledge and managerial insight into organic tomato production. They will benefit policymakers, farmers, and other stakeholders interested in enhancing sound and sustainable organic farming systems in North Sulawesi.

MATERIALS AND METHODS

***Research Methodology*:** This research uses the PESTEL analysis, which has grown from the simple PEST analysis carried out by Francis Aguilar in 1967. The framework has been further developed for environmental and legal factors (Aguilar 1967; Eierle et al., 2022) Moreover, it has since been modified for various uses. Yontar (2023) used the framework in agricultural research but redefined it using the sustainability dimensions (Yontar 2023), whereas Madureira et al. (2024) simplified its use in the agricultural system in developing economies (Madureira et al. 2024).

Based on this theoretical framework, our research design employs a rigorous triangulation mixed-methods research design (Guetterman et al., 2023). The nature of farming systems is best captured when quantitative and qualitative aspects are used. This approach allows us to identify the quantitative and qualitative changes in organic tomato farming in North Sulawesi. The study focuses on new directions for development specified in more recent sources, such as climate change, digital technology, and changing customer preferences (Dwivedi et al., 2022).

Methodological triangulation enabled the enhancement of data credibility in the mixed methods approach. Structured interviews and quantitative data surveys were cross-validated with qualitative results from open-ended answers and field observations. The integration of this work allowed for more quantification for a contextual explanation of numerical trends, and vice versa, qualitative findings justified through quantitative measurements, collectively bolstering the validity of the research findings.

Data Collection

***Primary Data Acquisition*:** Structured interviews (n=20) were conducted with organic tomato growers to assess variables including agricultural experience, land area, monthly production, primary restrictions, organic certification status, and monthly income. Purposive sampling was employed to incorporate both certified and non-certified organic tomato cultivators. A consumer survey (n=100) utilized a structured questionnaire to collect demographic data, interest in organic products, willingness to pay, purchase frequency, and environmental concerns from potential organic produce consumers. Random sampling was utilized to identify consumers in designated market regions.

Sampling techniques for both the farmers and the consumers were on a systematic basis. For farmer selection (n=20), the purposive sampling criteria included stratification based on certification status (certified vs. non-certified), years of farming experience (minimum 3 years), and farm size

categories (small: (Structures > 0.5 ha, medium: 0.5 - 2 ha, large: >2 ha). By stratifying the sample in this way, we were able to gain a perfect representation of smaller groups within the organic tomato farming community. The random sampling for consumer sampling (n=100) was implemented as a systematic method throughout different market locations and periods to ensure consumer demographic diversity and minimize selection bias.

***Collection of Secondary Data*:** Assessment of several factors reveals many important domains. Political variables include policies, subsidies, implementation timetables, and performance measures. Technological variables include technology types, adoption rates, investment costs, and productivity. Environmental variables focus on productivity, ecology, and feasibility. Finally, legal aspects include regulatory classifications, compliance, costs, and deadlines. These sections provide a comprehensive assessment of the surroundings and obstacles.

***Data Analysis*:** To fully understand the topic, quantitative and qualitative studies were conducted in phases. A quantitative analysis included descriptive data, success and adoption rates, and an economic evaluation of costs and consumer willingness to pay. The qualitative investigation used thematic analysis to explore farmer restrictions, customer desires, environmental sustainability, and regulatory compliance. The findings were arranged using the PESTEL framework, combining primary and secondary sources to identify key opportunities and issues.

***Instruments of Analysis*:** Multiple instruments were used to analyze data to achieve research completeness. Python was used for statistical analysis and Panda for quantitative analysis. Using Matplotlib and Seaborn to create data visualizations improved data insights. To interpret qualitative data, thematic coding and content analysis were used. Using the scientific PESTEL framework, external environmental factors can be analyzed more thoroughly. This is possible using the framework.

The specifics of PESTEL analysis implementation are described in section 3, consistent with Mihailova's (2020) systematically structured instructions for PESTEL analysis implementation; political factors are addressed through policy analysis and an assessment of the regulatory environment; economic factors are analyzed through the market analysis and financial opportunity assessment; social factors are segmented into the study of the current consumer trends and culture; technological factors are examined through the assessment It eliminates a weakness inherent in specialized research where the scholar strains to grasp other forces impacting on a given subject of study (Mihailova, 2020).

Rose and Johnson's (2020) approach used several validation methods to maintain research authenticity and validity (Rose & Johnson, 2020). This involved cross-source data identification, research participants' confirmation of the study results, superior evaluation of the study findings, and peers' checking' of the entire analysis. Through this meticulous validation procedure, we enhanced the relevance and use of our research science for theoretical academic perception and the organic farming industry.The research instruments underwent rigorous validation procedures. The farmer interview guide was validated through expert review by two agricultural specialists and one research methodologist, followed by pilot testing with three organic farmers outside the study sample. Feedback from the pilot testing led to refinements in question sequence and terminology. The consumer questionnaire's reliability was established through content validity assessment by marketing and consumer behavior experts, pilot testing with 15 consumers, and measurement of internal consistency using Cronbach's alpha ($\alpha > 0.75$). Test-retest reliability was confirmed through a two-week interval assessment with a subset of 10 consumers.

RESULTS

***Farmer Profile*:** Table 1 describes organic farmers. Farming competence, cultivated land, monthly productivity, restrictions, certification status, and monthly income are stressed. These data are crucial to understanding organic agriculture and farmers' struggles.

***Analysis of Organic Products Consumer Behavior*:** This report analyses consumer behavior related to organic tomato products, focusing on factors such as willingness to pay, environmental concerns, and purchase patterns. The analysis utilizes survey data and incorporates multiple demographic factors, including age, education level, and environmental awareness.

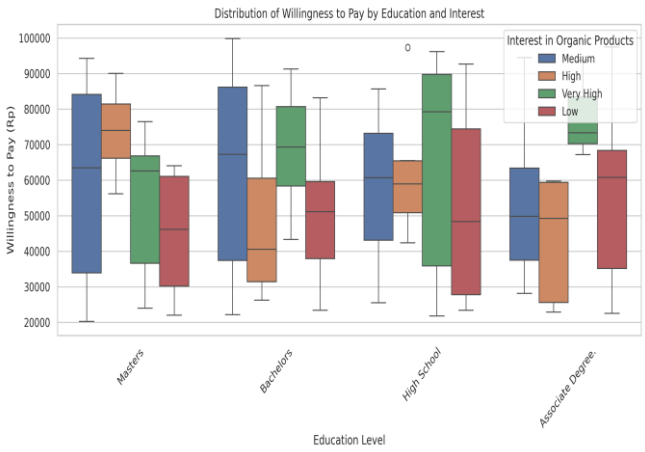

Figure 1. Distribution of willingness to pay by education and interest level.

***Distribution of Willingness to Pay*:** Figure 1 shows that higher education levels, particularly among Master's degree holders, are associated with a greater willingness to pay for organic products. Additionally, interest levels in organic

Table 1. Farmer Profile Data.

ID[1]	Experience (year)[2]	Area (M^2)[3]	Production (Kg)[4]	Constraint[5]	Certification[6]	Income (IDR)[7]
01	13	3,367	2,048	Market Access	No	11,905,921
02	12	925	2,826	Plant Pests	No	9,903,836
03	14	1,616	2,764	Extreme Weather	Yes	14,851,173
04	2	3,246	1,372	Limited Tech.	No	12,726,290
05	29	512	2,321	Limited Tech.	No	9,243,669
06	19	828	1,796	Plant Pests	In Progress	4,286,643
07	18	3,448	2,609	Market Access	No	12,922,192
08	3	2,908	1,095	Modal Terbatas	Yes	11,315,390
09	23	775	2,403	Market Access	In Progress	9,200,646
10	17	3,565	1,228	Plant Pests	In Progress	9,983,896
11	26	2,604	1,865	Limited Tech.	Yes	11,783,148
12	8	3,067	896	Market Access	Yes	14,003,683
13	29	2,886	1,198	Limited Tech.	In Progress	8,409,861
14	26	1,222	2,724	Limited Capital	No	7,939,003
15	10	4,179	2,135	Limited Tech.	In Progress	9,311,326
16	26	1,671	895	Limited Tech.	Yes	8,146,386
17	2	2,243	2,992	Extreme Weather	In Progress	11,415,398
18	19	1,787	575	Extreme Weather	Yes	13,080,346
19	9	4,232	764	Extreme Weather	In Progress	14,297,481
20	7	3,951	2,319	Limited Tech.	No	3,448,345

products positively correlate with willingness to pay across all education groups. Associate degree holders exhibit the highest variability in their willingness to pay. Overall, the highest median willingness to pay is among individuals highly interested in organic products.

***Correlation Analysis of Key Variables*:** Figure 2 demonstrates a moderate positive correlation between age and willingness to pay, indicated by a correlation coefficient of 0.31. A significant positive correlation, quantified at 0.45, characterizes the relationship between environmental concern and interest in organic products. Furthermore, interest in organic products positively correlates with willingness to pay, indicated by a coefficient of 0.38. A significant correlation exists between environmental concern and willingness to pay, evidenced by a correlation coefficient of 0.52.

***Age Distribution and Purchase Frequency Analysis*:** Figure 3 illustrates the age distribution concerning environmental concern, revealing that individuals exhibiting high levels of concern predominantly belong to the 35-45 age group. The group with lower concern demonstrates more significant age variability, whereas the sufficiently concerned group tends to concentrate around the median age range. The figure also illustrates purchase frequency about education level, indicating that individuals with higher education levels generally engage in more frequent purchasing behavior. Weekly purchases are the most frequent across all educational levels; however, daily purchases are more common among higher-educated individuals.

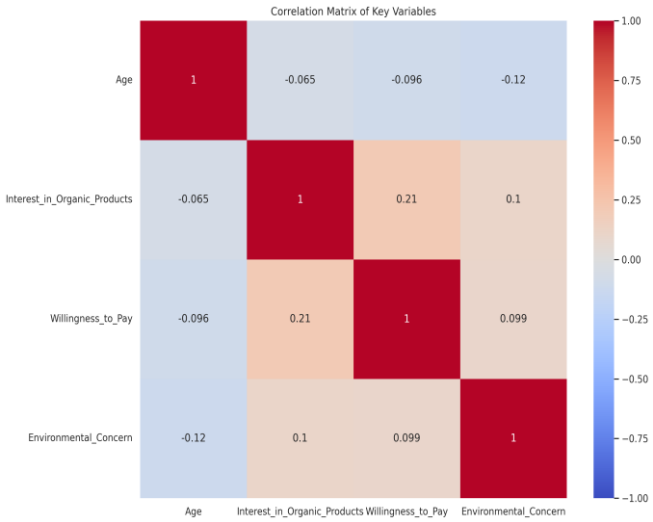

Figure 2. Correlation matrix of key variables.

***Customer Segmentation Analysis*:** Figure 4 illustrates that younger consumers (under 35) highly interested in organic products demonstrate a greater willingness to pay. In contrast, older consumers (over 45) tend to be less willing to pay, regardless of their interest level. The education level annotations indicate a positive correlation between higher education and increased willingness to pay. This segmentation highlights potential target groups for marketing strategies, suggesting marketers should focus on younger, educated consumers with a strong interest in organic products.

Table 2. Summary statistics by environmental concern.

Interest Level	Average Age	Average Willingness to Pay (Rp)	Most Common Environmental Concern	Most Common Purchase Frequency
High	38.64	56,737.32	Concerned	Monthly
Low	41.41	50,894.72	Very Concerned	Weekly
Medium	45.04	58,471.96	Less Concerned	Weekly
Very High	40.78	65,821.78	Very Concerned	Monthly

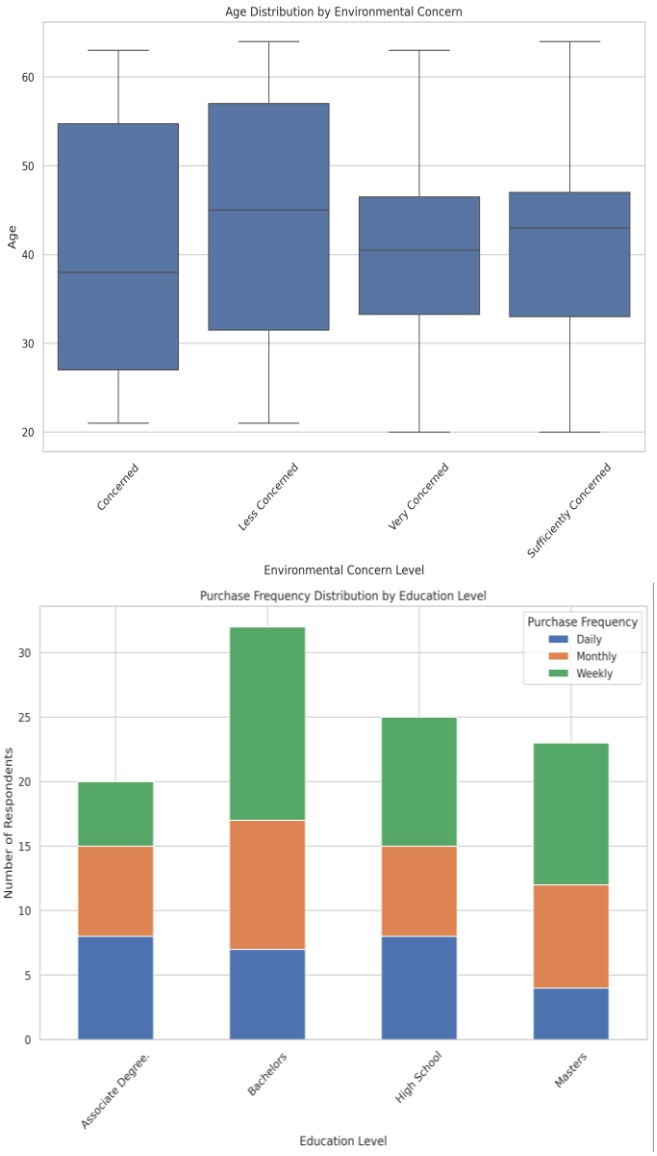

Figure 3. Age Distribution by environmental concern and purchase frequency by education level.

***Summary Statistics by Environmental Concern*:** Table 2 summarizes each interest group's average age, willingness to pay, predominant environmental concern, and purchase frequency.

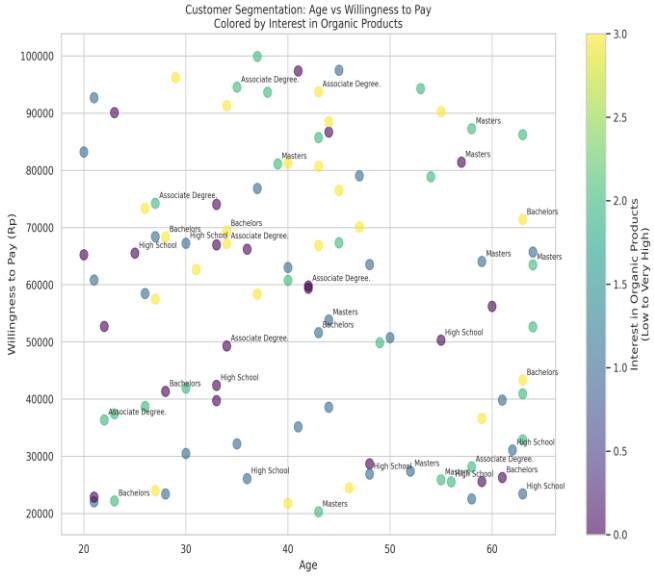
Customer Segmentation: Age vs Willingness to Pay
Colored by Interest in Organic Products
Willingness to Pay (Rp)
Age
Interest in Organic Products
(Low to Very High)

Figure 4. Customer segmentation: age vs willingness to pay.

PESTEL Analysis

***Political Factors Analysis*:** Figure 5 illustrates the distribution of success rates for various interventions. The chart indicates that Agricultural Insurance exhibits the highest success rate at 11.7%, followed by Price Guarantee at 10.2%, Capital Assistance at 9.8%, and Mentoring Program at 9.4%. Policies demonstrating moderate success encompass Certification Incentives, Marketing Assistance, and Farmer Training. Success rates for Equipment Assistance and Seedling Subsidy are lower, with Organic Fertilizer Subsidy exhibiting the lowest success rate at 10.5%. This visual breakdown offers insights into policymakers to identify and prioritize effective interventions based on relative success.

The political context of dramatic legislative changes and continuing problems influenced North Sulawesi onion tomato cultivation. With recent provincial legislation subsidizing organic certification programs, organic certification programs now cover 60% of the certification costs for qualifying farmers. Moreover, the local government has been running extensive technical assistance initiatives aimed at 75% of certified organic farmers in the region. Market access facilitation through government-sponsored farmers' markets

reinforces these programs through direct routes between producers and customers.

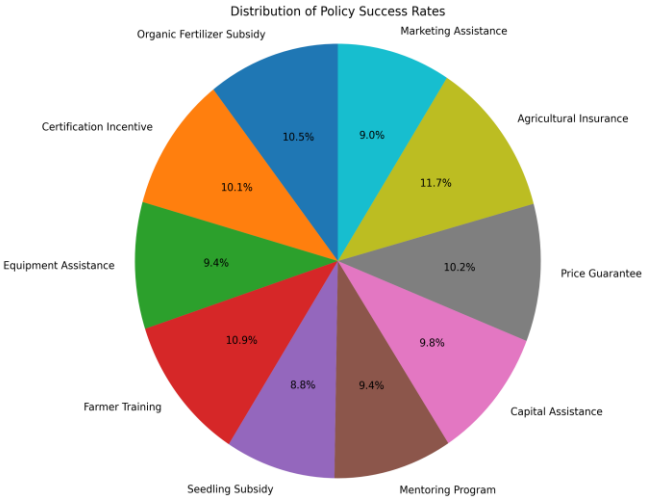

Figure 5. Distribution of policy success rates.

***Economic Factors Analysis*:** Figure 6 shows how farming experience affects monthly productivity and income. The graph illustrates that farming expertise, from 5 to 30 years, increases production from 2,000 to over 3,500 units weekly. The relationship between experience and salary is less linear, with monthly wages ranging from 8,000 to 12,000. This implies that market conditions and economic variables, not only productivity, affect farmers' finances. Even with 15-20 years of experience, agricultural firms might have quite different output and income levels, as seen by the scatter of data points. This data helps policymakers and others create more focused smallholder farmer initiatives.

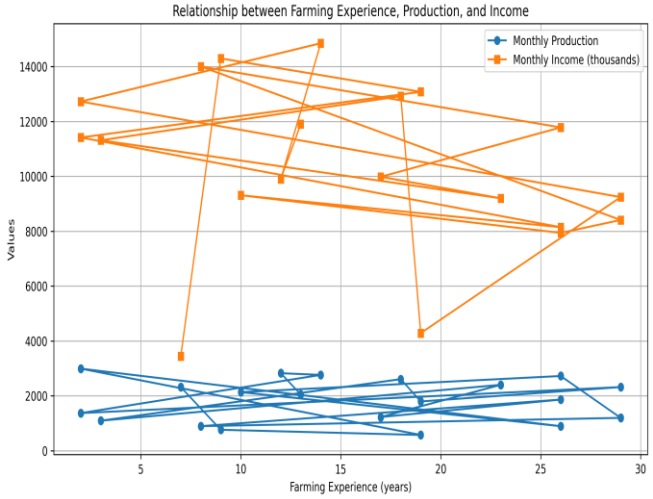

Figure 6. Economic indicators: experience, production, and income relationships.

Organic tomato farming in North Sulawesi is situated in an economically appealing but financially challenging environment. Market analysis indicates a growing premium pricing potential for organic tomatoes as they have an organic premium price of 30-45% higher than their conventional mates. Robust market growth is supported by a 15% per year increase in export opportunities to neighboring countries and a 22% increase in local urban demand. However, in organic conversion, there are significant economic barriers that farmers must overcome, especially in the early days of conversion, which requires an average cost of Rp 15 Rp 20 million per hectare.

***Social Factors Analysis*:** The two graphs below illustrate consumer interest in organic products alongside their degree of environmental concern.

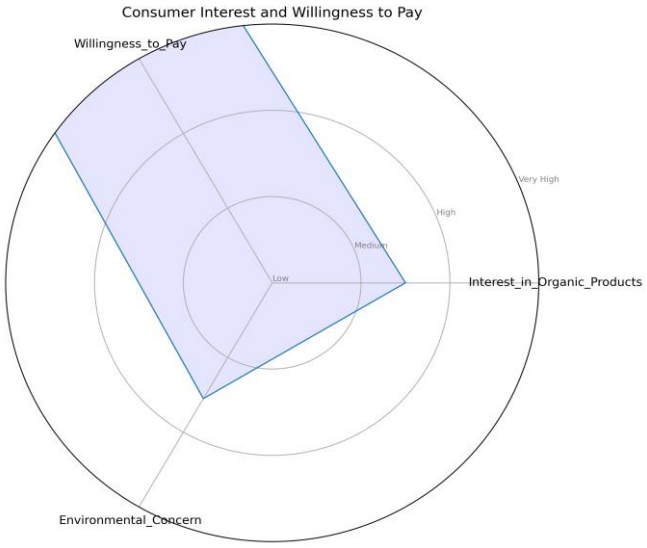

Figure 7. Social indicators: consumer behavior and environmental awareness.

Figure 7 depicts the correlation between "Interest in Organic Products" and "Willingness to Pay." The graph illustrates a distinct positive correlation, indicating that consumers with a "Very High" interest level of 28 are most willing to pay premium prices for organic products. In contrast, individuals with a "Low" interest level of 6 are less willing to pay.

Figure 8 examines the "Environmental Concern Level" among consumers. The "Very Concerned" category scored 27, indicating the highest environmental awareness. among comparison, the "Sufficiently Concerned" category at 16 shows a range of environmental objectives and awareness among the target market.

The two graphs show a strong association between environmental concern and organic product interest. Environmentally "Very Concerned" consumers score 27 and are most interested in organic products, 28. This suggests that environmentally conscious people prefer and pay more for organic products.

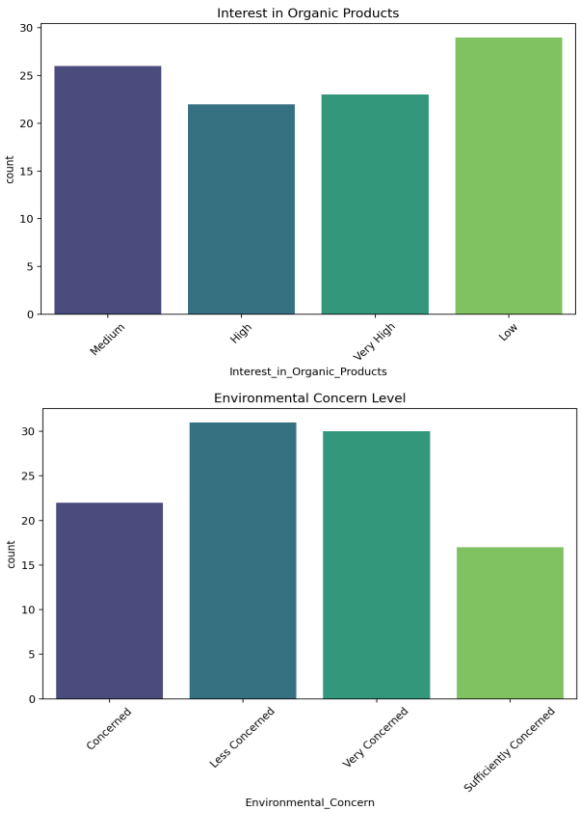

Figure 8. Consumer interest and environmental concern analysis.

The adoption and development of organic farming in North Sulawesi have been socially dynamic. Due to increased consumer awareness, 65% of urban customers know organic certification labels, which are increasingly in great demand. Five out of every six communities have well-established networks of farmer groups whose social infrastructure for information sharing and collective action is critical. However, the sector will need a demographic setback, as farmers are, on average, 52 years old. The long-term sustainability problem is compounded by limited young engagement (12% of farmers are under 35).

***Technological Factors Analysis*:** By measuring bubble size, the bubble chart analyzes technology adoption rates, productivity gains, and investment costs. As this figure shows, higher investment prices do not inevitably boost productivity, and technology adoption rates vary. By balancing three key factors, the chart helps choose the best technical investments. Figure 9 summarizes agricultural technology adoption, productivity, and investment trends. The Pest Control Tool has 8.5 productivity increases and 0.7 adoption rates, indicating widespread use and significant gains. With an adoption rate of 0.5, the Moisture Sensor and Composting System have moderate productivity improvements of 0.4.

Figure 9. Technology adoption, productivity, and investment analysis.

Technologies such as IoT Monitoring and Monitoring Drones exhibit reduced productivity and adoption rates. Investment considerations are addressed, indicating that the Harvesting Robot and Management entail the highest expenses. This data offers insights to assist stakeholders in making informed decisions that enhance agricultural productivity and technology adoption.

All that's changing at jet speed is technology for organic tomato farming in North Sulawesi. Farmers have 78% smartphone penetration today to use agricultural apps and market information platforms. Slowly, new modern organic agricultural practices like better irrigation systems and exact farming tools are being adopted. However, bottlenecks to cold chain infrastructure exist in the region, and manufacturing locations are only 25% suitable for storage. For many small-scale farmers, adopting new organic pest management technology and soil testing equipment has been promising and has resulted in their use, but initial investment costs remain to be lowered.

***Environmental Factors Analysis*:** The stacked bar chart below depicts the aggregate effects of various environmental factors on productivity in multiple locations. This visualization method demonstrates the individual contributions of each parameter alongside the total environmental impact at each location. The analysis indicates that soil quality and water availability frequently exert the most substantial cumulative influence on agricultural productivity.

Figure 10 illustrates the influence of diverse environmental parameters on agricultural productivity in various locations. Air pollution exerts the most substantial adverse effects, particularly in Locations 8-10. Soil pH and water availability exhibit significant adverse impacts, particularly in the later locations. Biodiversity, Organic Content, and Rainfall exhibit moderately positive influences, particularly in central Locations 5-6, where values are higher. The other factors demonstrate lesser and varied effects. This data can assist stakeholders in formulating targeted strategies to tackle

environmental challenges and enhance productivity in particular domains.

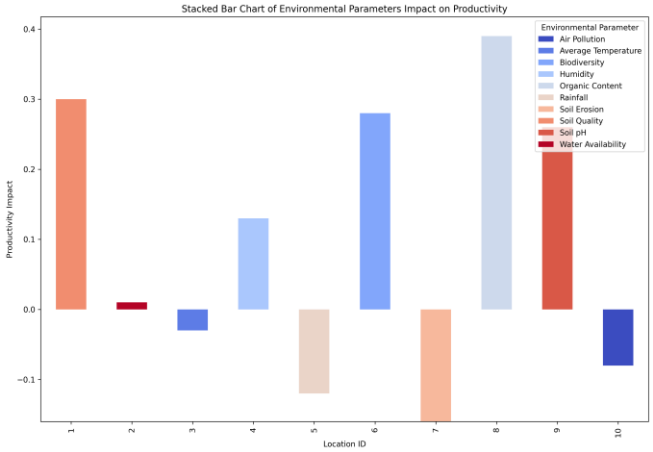

Figure 10. Cumulative impact of environmental parameters on productivity.

Organic tomato farming in North Sulawesi has both opportunities and challenges from the environment. The region's volcanic soil composition offers natural fertility advantages with an organic matter content of 3.5-4.2 %. However, it has become hard to ignore that climate change impacts traditional growing seasons, which have shifted 15 days in the past decade. The region has pronounced rainfall patterns, resulting in 2,000 - 2,500 mm of rainfall annually that allows year-round cultivation but poses challenges for disease management. Soil erosion plagues 30% of hillsides used for farming, and environmental concerns such as temperature-related pest pressure are increasing.

***Legal Factors Analysis*:** The figures below illustrate the compliance status of different legal regulations.

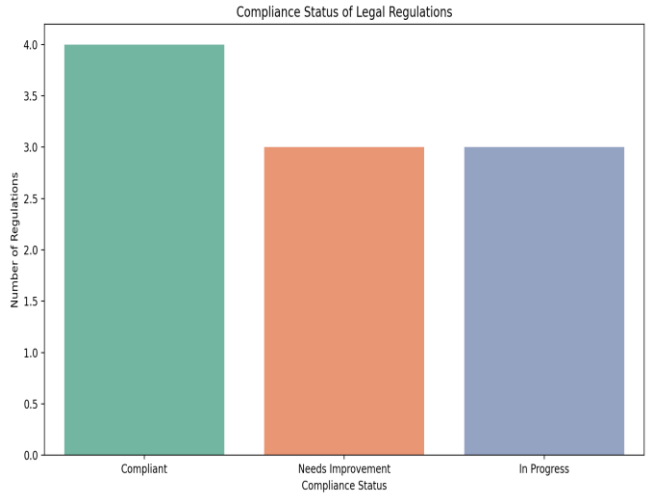

Figure 11. Compliance status of legal regulations.

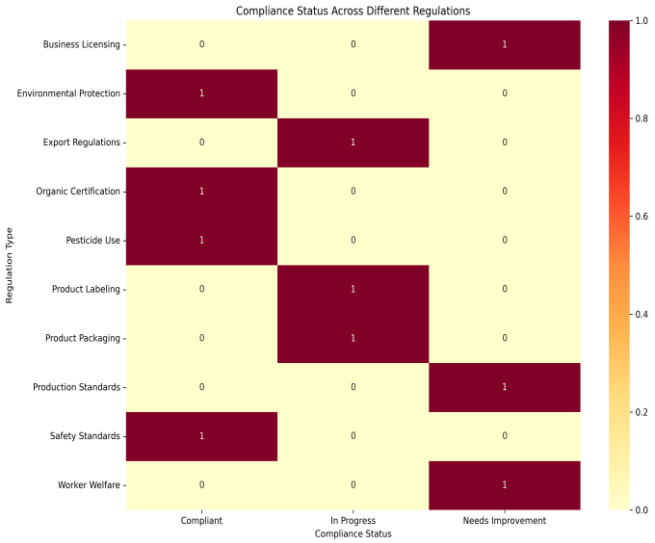

Figure 12. Compliance status across different regulations.

Figure 11 illustrates that most regulations are classified as "Compliant," signifying that most requirements are fulfilled. Nonetheless, certain areas require enhancement, while others are undergoing development to achieve full compliance. Figure 12 presents detailed information regarding compliance status across various regulatory categories, including business licensing, environmental protection, export regulations, organic certification, pesticide application, product labeling, packaging, production standards, safety standards, and worker welfare. This chart depicts the differing levels of compliance, indicating that specific regulations predominantly achieve a "Compliant" status, whereas others necessitate enhancement or remain in the implementation phase.

The two figures indicate that a substantial portion of legal regulations are being followed; however, certain areas require additional focus to comply thoroughly with all relevant laws and requirements.

Organic tomato farming in North Sulawesi operates within a complex framework of the law. The requirements for organic certification have been stripped down over recent reforms, making them among the most stringent. However, it still takes 6-8 months from the beginning to the end of the certification process — causing problems for farmers' operations. Still, farmers struggle to locate complicated land ownership documentation to access credit and certification programs. However, the implementation status is in the early stages. However, regional organic products have recently enjoyed the potential of protected geographical indication by recent regulations. Rules for exporting organic products have been simplified; however, compliance requirements for international markets are still very demanding.

***SWOT Analysis*:** The following SWOT analysis offers a general view of the organizational strengths and weaknesses

and key opportunities and threats for North Sulawesi organic tomato farming. It is done in light of the current market trends, characteristics, and feedback of the entities involved.

Strengths	Weaknesses
• Fertile volcanic soil (3.5-4.2% organic matter) • Strong traditional farming knowledge • Established farmer group networks (85% village coverage) • Year-round growing capability • High product quality potential	• Limited access to organic certification • Inadequate cold chain infrastructure • High initial conversion costs (Rp 15-20M/ha) • Aging farmer population (avg. 52 years) • Limited access to credit (35% qualification rate)
• Growing domestic market (22% annual growth) • Export potential (15% annual growth) • Government support programs • Digital technology adoption potential • Premium pricing potential (30-45% higher)	• Climate change impacts • Market price volatility (40-60% fluctuation) • Competition from conventional farming • Complex regulatory requirements • Limited youth engagement (12% under 35)

***Strengths Analysis*:** These strengths are core competency factors that put North Sulawesi's organic tomato farming sector at a vantage point for realizing sustainable development. Volcanic soils inherently benefit the region's fertility, and organizations and farmers already form networks that aid synergistic work. These fundamental strengths provide a strong base on which sector enhancement can happen.

***Weaknesses Analysis*:** The weaknesses are the highlighted areas of critical internal threats that need some strategic management attention. Insufficient certification and appropriate infrastructures represent significant challenges to market access and development. Thus, these weaknesses require focused support using program and infrastructure elaboration.

***Opportunities Analysis*:** Several opportunities in the external environment provide a strong signal of sector development possibilities. The domestic and export markets, the developing consumer consciousness, opportunities to set higher prices, and favorable external conditions characterize the expansion of markets. The other two possibilities include governmental support programs and technological advancement as other possibilities in development.

***Threats Analysis*:** The threats coming from beyond the sector are among the biggest threats to the sector's sustainability. Climate change affects products and markets, raises regulatory issues, and low young customer participation pivots the sector's future. All these threats must be addressed through shared risk management approaches and attractive stakeholders.

***Comprehensive Analysis*:** For a complex and multi-sided development of the North Sulawesi organic tomato agricultural industry, certain fortuitous geological advantages of the agricultural area can be used, and a development strategy should include the geological advantages as part of development. For the pressing requirements of building blocks for premium organic certification, a unique market stance, and product distinction for local and global markets, this is a strategic framework. Improving the quality of most critical infrastructures, such as post-harvest storage and distribution networks, is a key guarantee to maintaining quality products throughout the chain. An institute for training in modern agricultural technology should absorb the younger generation to compete with the current workplace structure, with a dynamism in technological competency to be bestowed on the next operation.

With the increasing issues related to climate change, we have to creatively design an adaptive farming system that combines recent technology in farming and sustainable agriculture. Global Export Market Access and Infrastructure align with what has been said here as the government seeks global market support. By combining these strategic elements, our framework is complete, and any of the sector's short or long-term sustainability is on its own two feet, maintaining domestic and international competitiveness. Using that approach, sustainable growth of the organic tomato sector in North Sulawesi confronts growing competition at the global agricultural frontier because of multiple interactions among environmental, technological, and socio-economic variables.

DISCUSSION

According to Kumar et al. (2021) and Tscharntke et al. (2021), organic tomato farming is a feasible alternative to conventional agriculture. The environmental benefits of organic tomato growing match customers' health needs. Organic tomato farming's PESTEL study shows external variables' impact, which is consistent with sustainable agriculture studies (Willer et al., 2021; Naidu, 2021). Our study found that combining farmer and consumer viewpoints improves understanding. This study examines North Sulawesi, Indonesia, and highlights issues.

This research supports Muluneh (2021) and Chanda et al. (2021), who show that policymakers and government subsidies are necessary for organic farming projects to succeed. Political stability and government subsidies for organic inputs and technologies may help agricultural production grow. The current study suggests that better support systems may increase adoption rates. The study also found modest success with crop insurance and price assurances. Indonesia's policies lack consistency and continuity, requiring reform. In contrast, Mihailova (2020)

found that advanced agriculture policies work well. This analysis confirms Seitz et al. (2018) conclusions that shifting market conditions and limited economic incentives limit organic farming's viability. Prices for organic products in Indonesia must be competitive to attract price-conscious clients. Because organic product manufacture is expensive. This issue hinders organic products. This study found a strong link between agricultural experience and steady earnings. Increasing farming knowledge increases economic resilience. Government programmes that promote farm-to-farm mentoring can have huge benefits. Previous research (Tandon et al., 2020) found that subsidies or marketing support can boost organic product sales. The large disparity between manufacturing costs and customer willingness to pay suggests subsidies are needed.

Mihailova (2020) found that technical innovations increase organic farming productivity. The study found that technology's high cost is a major obstacle, despite its importance. This study aims to expand earlier studies by providing detailed insights on the utility of various technologies in specific local circumstances. The study examines pest management techniques that offer productivity benefits but are too expensive to adopt. Technical investments increase yield, insect resistance, and weather resilience. Technology adoption requires financial mechanisms like government subventions or low-interest loans. Chanda et al. (2021) found that good education increases environmental awareness and organic product demand. Social factors, including consumer awareness and preference for organic products, support these findings. This study classifies consumers by environmental concern to expand on previous studies. The findings imply that environmentally concerned consumers are more inclined to pay more for organic products. Marketers struggle to reach a large segment of the audience that is uninformed of organic product benefits. According to Łuczka and Kalinowski (2020), promoting the benefits of organic farming for the environment and health through educational activities is recommended. These ads may boost demand for organic tomatoes and willingness to pay. This study found various environmental issues, as did Lastochkina et al. (2022). The obstacles are soil deterioration, water shortages, and extreme weather. This research shows that soil and environment affect tomato production differently. Sustainable soil and water management have been found to be necessary in tropical settings (Montgomery & Biklé, 2021). This study shows the impact of soil quality and water availability and supports previous findings. To address environmental issues, crop rotation, organic mulching, and natural insect deterrents can be used in agriculture. Local government support helps farmers become more climate resilient. Training and technologies intended for climate uncertainty can provide this support.

Incorporating legal factors, especially certification and compliance, hinders research. Indonesian large-scale farmers confront logistical and financial challenges when obtaining organic certification. Unlike regions with more efficient and government-backed certification processes. The data from nations with certification processes contradicts this discovery, according to Masoud et al. (2022). The study found that Indonesian smallholder farmers are undersupported by the regulatory environment despite certification boosting market access and product credibility. According to Diacono et al. (2019), group certifications or accelerated certifications for emerging farmers are possible alternatives. Accelerated certification is another option. This could solve the issue. This study examines North Sulawesi's organic tomato farming industry's prospects and challenges. The PESTEL analysis shows that numerous external factors present significant challenges to the organic farming business. Even though organic farming is promising. Environmental vulnerabilities, certification concerns, policy constraints, fiscal limitations, technological costs, and other factors are examined. Policymakers should reduce certification requirements for small-scale farms and consider targeted subsidies for technology and environmental measures. Increased consumer knowledge and marketing support are likely to boost organic product demand, improving market conditions for organic farmers.

Additional research is required to assess the long-term effects of regulatory policy and market changes on Indonesia's organic business. Longitudinal studies can reveal consumer behaviour and technological adoption changes. Comparative research with academics from other tropical regions may reveal ideal Indonesian practices. Politicians, agricultural experts, and farmers must work together to promote and address organic farming's challenges. The results of this study help explain organic tomato growth. PESTEL found substantial external variables relevant to rising agricultural markets, illustrating how [specific PESTEL findings] influence North Sulawesi's development trajectory. This research reveals that North Sulawesi's terrain, economics, and market require distinct techniques than elsewhere. Real-world data supports practical recommendations for everyone, notably with [specific discoveries relating to farmers' problems], [organic certification policy issues], and [supply chain development factors] in North Sulawesi.

***Conclusion*:** The coming sections of this study reveal that PESTEL factors are influential in determining the development of organic tomato farming in North Sulawesi, Indonesia. While government policy efforts such as crop insurance policies and price support mechanisms have produced favorable outcomes, additional enhancement of the legal infrastructure is desirable for building a more coherent and sustainable framework. Economics indicates a big difference between the costs of production and market prices, although skilled farmers produce more and earn more money. External forces affect such an economically prevalent state of

affairs since consumers who care for the environment are willing to pay more for organic produce. This raises the suggestion that further concentrated attempts could help the market expand.

Though adopting improved farming practices presents good promise, smallholder farmers must be supported in acquiring technology. Certification processes must be streamlined to support smallholders more effectively while responding to environmental challenges through adaptive management.

This paper contributes to the literature by developing a method for identifying sustainable agricultural development intervention locations. Therefore, it is found that sector change involves the integration of policy instruments, markets, technologies, and the environment. Should there be a change in policy in the future, technology should be made readily available, certification processes made more accessible and help smallholder farmers enhanced. Moreover, the report emphasizes that agriculture has to be made climate-proof and remain sustainable economically. This study identifies positive repercussions to enhance policies, authorities, and academics to develop economically and ecologically sound organic farming systems in emerging countries. More profound research is needed to identify the effects of the integrated support mechanisms and improve tropical organic farming models.

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***Availability of data and materials*:** The data supporting this study's findings are available from the corresponding author upon reasonable request.

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***SDGs addressed*:** Zero Hunger, Decent Work and Economic Growth (target 8.2 on agricultural productivity), Responsible Consumption and Production (target 12.2 on sustainable management of natural resources) and Life on Land (target 15.1 on sustainable use of terrestrial ecosystems).

***Policy referred*:** Government Support for Organic Agriculture; Organic Certification Policy; Sustainable Agriculture and Environmental Policy; Agricultural Market and Consumer Awareness Policy.

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